United States Patent [19]

Coleman et al.

[11] **4,024,408**

[45] **May 17, 1977**

[54] **MINIMUM START TIMER FOR STARTING A DIESEL ENGINE**

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[73] Assignee: **Caterpillar Tractor Co.,** Peoria, Ill.

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[52] **U.S. Cl.** ..... **290/37 R;** 290/38 R; 123/179 R

[51] **Int. Cl.²** **F02N 11/08**

[58] **Field of Search** ..... 18/484, 434; 290/DIG. 1, DIG. 3, DIG. 10, DIG. 11, 37 R, 38 R, 38 C, 38 E, 37, 38; 307/133, 141; 123/179 R, 179 C, 179 D, 179 H; 340/52 R

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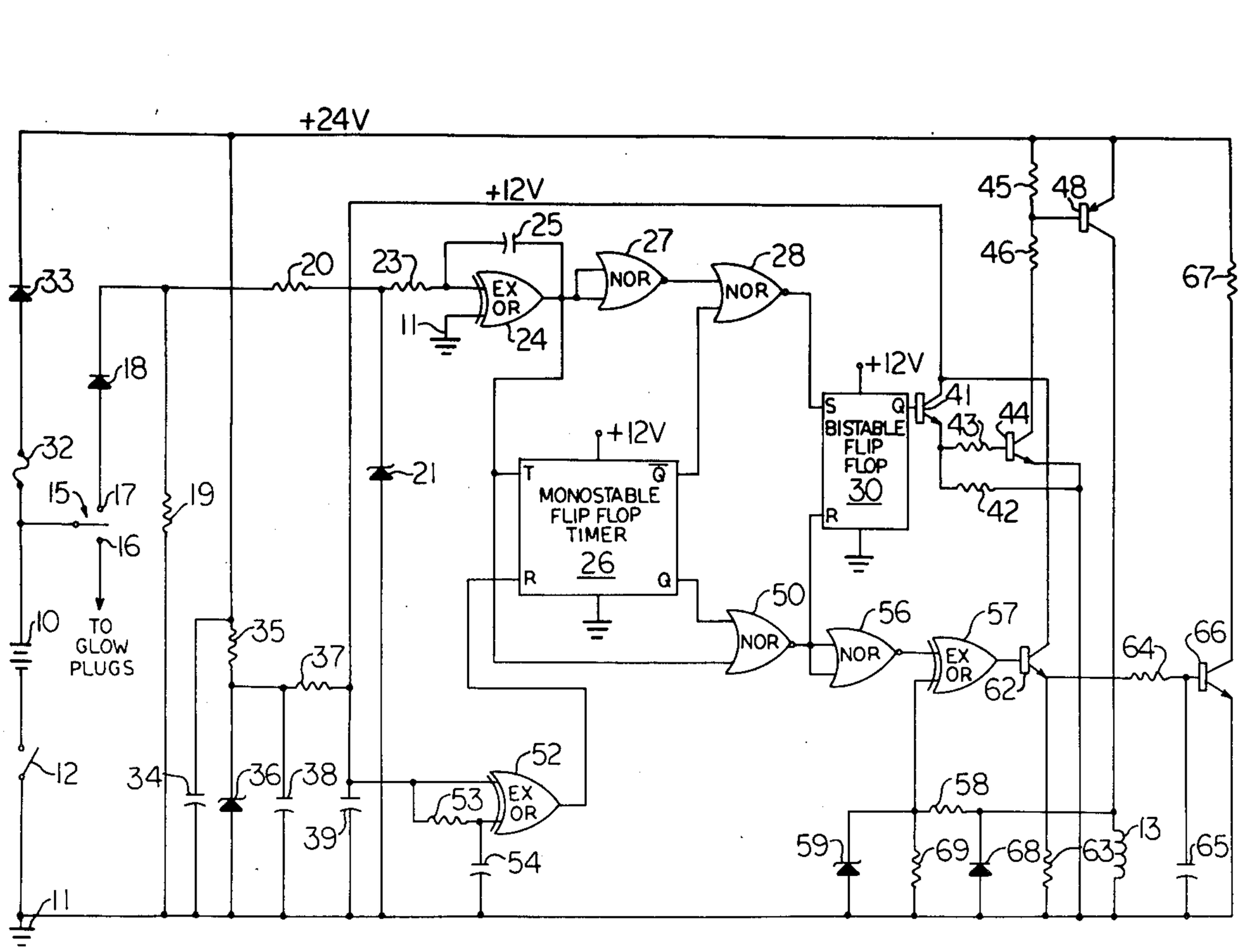
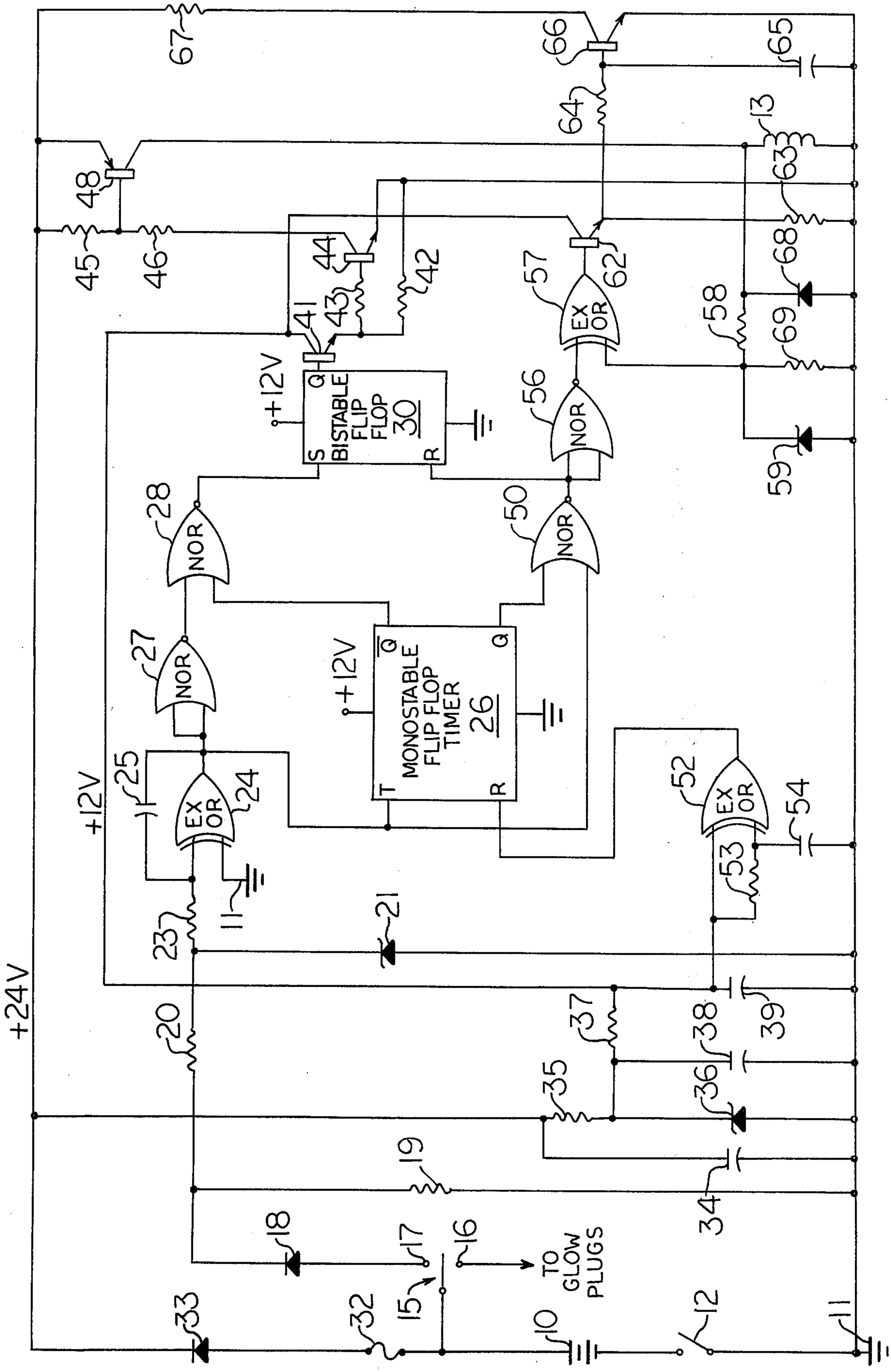
Attorney, Agent, or Firm—Wegner, Stellman, McCord, Wiles & Wood

[57] **ABSTRACT**

A start timer circuit for a diesel engine is responsive to the operator actuated start switch. The timer circuit energizes the engine start motor circuit for at least a minimum time, sufficient to avoid sustained firing of the engine at a low speed. Safety circuits prevent false energization of the start motor circuit in the event of malfunction or failure of various circuit components.

18 Claims, 1 Drawing Figure

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MINIMUM START TIMER FOR STARTING A DIESEL ENGINE

BACKGROUND OF THE INVENTION

This application is concerned with a timer circuit for controlling the start motor of a diesel engine.

Diesel engines are generally provided with an electric start motor which cranks the engine at a speed of the order of 100 RPM. The drive train which connects the engine with a transmission or other load often has a torsional resonant speed or speeds and the drive train is designed to place these resonances below the idling speed of the engine. Typically, a resonant speed may occur between the cranking speed and the low idle speed (e.g., 600 RPM) as at about 200 RPM. When a cold engine is started, it is common to operate the start motor for a sufficient length of time to ensure acceleration past the low speed resonance. However, when a hot engine is restarted after a short shut-down, it will sometimes sustain fire at a speed as low as 100 RPM. The engine at this speed has very little torque, insufficient to accelerate through resonance. If the operator turns off the start motor at such a low speed, damage to the drive train may result. If, however, the start motor remains energized, the added torque it provides ensures that the engine will accelerate through the drive train resonance. We have found that with a typical diesel engine, the start motor should be operated for at least 0.8 second.

A principal feature of the invention is a diesel engine start motor control circuit which includes an operator actuated start switch, a timer initiated by actuation of the start switch and having an output with a minimum duration which is independent of the time for which the start switch is actuated, and a start motor circuit energized by the timer output.

Another feature is that the start motor circuit is energized in response to a combination of the timer output and actuation of the start switch so that the start motor circuit remains energized for the longer of the duration of the timer output and start switch actuation. More particularly, the timer has a monostable flip-flop circuit which is actuated by the start switch and has an output with a duration which is independent of the time for which the start switch is actuated. A bistable flip-flop latch circuit has an input responsive to a combination of the timer output and actuation of the start switch and has an output which controls energization of the start motor circuit. The bistable flip-flop latch circuit has a reset input which is responsive to the concurrent absence of actuation of the start switch and the timed output from the timer so that the bistable latch circuit is not reset until the timer is timed out and the operator has released the start switch.

A further feature of the invention is the provision of safety features in the start motor control circuit. One such safety circuit provides for resetting the monostable timer flip-flop when the vehicle disconnect switch is closed. Another compares the condition of the start motor circuit with the inputs from the start switch and timer. If they are not in agreement, the circuit is disabled by blowing a fuse.

Further features and advantages of the invention will readily be apparent from the following specification and from the drawing which is a schematic circuit diagram illustrating a preferred embodiment of the invention.

The start motor timer circuit is powered from a suitable voltage source as battery **10,** one terminal of which is returned to a common connection or ground **11** through vehicle disconnect switch **12.** The start motor circuit is represented by driver coil **13** which may, for example, actuate a relay to apply battery power to the electric start motor and engage the start motor drive pinion with the diesel engine (not shown).

Start switch **15** when closed with lower contact **16** energizes glow plugs to heat the engine for starting. When switch **15** is closed with its upper contact **17** the timed operation of the start motor circuit is initiated. Battery potential is applied through diode **18,** which provides protection against reverse potentials, and across shunt load resistor **19** to the series combination of current limiting resistor **20** and the Zener diode voltage regulator **21.** The voltage across the Zener diode is connected through the resistor **23** with one of the inputs of EX OR **24,** the other input of which is returned to ground **11.** In the absence of an input signal to EX OR **24,** its output is a logic O. Capacitor **25** is connected between the output of EX OR **24** and the input to which the resistor **23** is connected. Resistor **23** and capacitor **25** provide a time delay so that the EX OR **24** does not have a logic 1 output immediately on closure of start switch **15.** When switch **15** is opened, capacitor **25** discharges through resistors **23, 20** and **19** delaying the logic O output of EX OR **24.** These time delays avoid false operation of the start motor circuit in the event of chatter of start switch **15.**

The output of EX OR **24** is connected with the T input of monostable oscillator timer **26.** When the EX OR output goes to 1, operation of the timer is initiated and the Q output goes to 1 and the Q output goes to O. These output conditions are maintained for the timing period, which may be of the order of one second.

The output of EX OR **24** is also connected with both inputs of NOR **27** which functions as an inverter. With a 1 applied to the inputs, the output is 0. The output of inverter NOR **27** and the Q output of timer **26** are connected as inputs to NOR **28,** the output of which is connected with the S or set input of bistable flip-flop latch circuit **30.** When NOR **28** has two 0 inputs, it has a 1 output, causing flip-flop **30** to assume the set condition with a 1 signal at the Q output.

The remainder of the circuit for energizing the start motor relay or driver coil **13** utilizes transistors powered directly or indirectly from battery **10.** In a typical circuit the battery has a voltage of 24 volts. It is connected through fuse **32** and isolating diode **33** with a shunt filter capacitor **34.** A low voltage power supply provides a reduced voltage, as **12** volts, for some of the transistors. Current limiting resistor **35** and Zener diode **36** establish the reduced voltage which is filtered by series resistor **37** and shunt capacitors **38, 39.**

Emitter-follower transistor **41** has its base connected with the Q output of bistable latching flip-flop **30** and its collector-emitter circuit connected through load resistor **42** across the low voltage power supply. The output of the emitter follower transistor is connected through isolating and current limiting resistor **43** with the base of driver transistor **44** which has an emitter-collector circuit connected through collector load resistors **45, 46** across battery **10.** Switching transistor **48** for start motor circuit coil **13** has its base connected with the junction of resistor **45, 46,** its emitter connected with the battery **10** and its collector connected through coil **13** with ground **11.**

A 1 signal from the Q output of bistable flip-flop **30** turns on emitter-follower transistor **41,** driver transistor **44** and switching transistor **48,** energizing the start motor. So long as the Q output of bistable latching flip-flop **30** remains at 1, the start motor circuit is energized.

After the timer **26** completes its timing period, which may be set by the selection of suitable resistor and capacitor components (not shown), its outputs reverse, Q going to 1 and Q to 0, regardless of whether start switch **15** is closed or is opened. The output of NOR **28** goes to 0. This, however, does not affect latching flip-flop **30,** which cannot change its condition until a 1 signal is applied to the reset input R.

The Q output of timer **26,** which provides one of the inputs from NOR **50,** goes to 0. The other input for NOR **50** is obtained from the output of EX OR **24.** If start switch **15** remains closed, this signal is a 1 and latching flip-flop **30** remains set. If, however, the operator has opened start switch **15,** the output of EX OR **24** is 0. With two 0 inputs, NOR **50** has a 1 output, resetting flip-flop **30** and terminating energization of the start motor circuit. Thus, so long as either bistable flip-flop timer **26** has not completed its timing period or start switch **15** remains closed, the start motor circuit is energized. Conversely, when timer **26** has completed its timing period and start switch **15** is open, the start motor circuit is deenergized.

In a typical diesel engine start system, the period for timer **26** may be of the order of 1.0 ± 0.2 seconds. It has been found that this is sufficient time for a hot engine to start and accelerate through the low speed resonance of the drive train.

The control circuit includes several safety features. When vehicle disconnect switch **12** is closed and prior to operation of start switch **15,** bistable flip-flop timer **26** is reset. This is accomplished by the circuit of EX OR **52.** One input is connected directly across filter capacitor **39** and thus goes to a 1 condition as soon as vehicle disconnect switch **12** is closed. The other input of EX OR **52** is connected across capacitor **39** through a time delay circuit including series resistor **53** and shunt capacitor **54.** So long as the signal at the other input remains at 0, EX OR **52** has a 1 output. The time period for the circuit is such that EX OR **52** has a 1 output for about 0.1 second, ensuring reset of the timer **26** so that the timer is ready for actuation when start switch **15** is closed.

If there is a failure in the timer, and no timing pulse is produced, the start cycle is not initiated. If, on the other hand, there is a failure in the NOR **28,** flip-flop **30** or the switching circuit of transistors **41, 44** and **48,** the control circuit is rendered inoperative.

A monitor circuit compares the condition of the actuating signals for the start motor circuit with the condition of the start motor circuit. If the signal and circuit conditions do not agree, fuse **32** is blown to prevent damage to the start motor or the control circuit. The inputs of NOR **50** represent the condition of start switch **15** and the output of timer **26,** the two signals which are required to set bistable latching flip-flop **30** and energize the start motor circuit. The output of NOR **50** is connected with both inputs of NOR **56,** which serves as an inverter, the output of which is connected as one of the inputs of EX OR **57.** The other input of EX OR **57** is derived from the voltage across start motor circuit driver coil **13.** The coil voltage is connected through current limiting resistor **58** with Zener diode **59,** and the diode voltage provides a logic 1 input signal to EX OR **57.** When both start enabling signals are present, the output of NOR **50** is 0 and the output of inverter **56** is a logic 1. Conversely, if both signals are not present at the input of NOR **50,** its output is a logic 1 and the output of inverter **56** is 0. EX OR **57** serves to compare the start circuit input signals with the condition of the start motor circuit. So long as the two inputs EX OR **57** are the same, the output is 0. If, however, the inputs differ, the output is a logic 1. If this difference should occur, driver transistor **62** is connected with the low voltage supply and the emitter is returned through load resistor **63** to ground **11.** The voltage across load resistor **63** is connected through a time delay circuit, series resistor **64** and shunt capacitor **65,** with the base of fail safe transistor switch **66** which has an emitter-collector circuit connected through current limiting resistor **67,** in series with diode **33** and fuse **32** across battery **10.** Conduction of transistor **66** causes fuse **32** to blow, disabling the circuit and preventing damage. The time delay afforded by resistor **64** and capacitor **65** prevents blowing fuse **32** if the input signals of EX OR **57** do not occur at precisely the same instant.

Diode **68** discharges the inductive field of coil **13** when the start circuit is deenergized, preventing possible damage to other circuit components.

If coil **13** is disconnected from the circuit, as for servicing or the like, and vehicle enable switch **12** is closed, leakage current through transistor **48** will build up a voltage on the lower input of EX OR **57** which could cause conduction of transistor **66** and blow fuse **32.** Resistor **69** connected in shunt with Zener diode **59** provides a return path for this leakage current.

What is claimed is:

1. A control circuit for the start motor of a diesel engine, comprising: an operator actuated start switch; a timer initiated by actuation of said start switch and having an output with a minimum duration independent of the time for which the start switch is actuated; and a start motor circuit energized by the output of said timer; and a circuit for providing a time delay between the operator actuated start switch and the timer, to avoid false operation of the start motor circuit in the event of chatter of the start switch.

2. A control circuit for the start motor of a diesel engine, comprising: an operator actuated start switch; a timer initiated by actuation of said start switch and having an output with a minimum duration independent of the time for which the start switch is actuated; and a start motor circuit energized by the output of said timer, wherein the start motor circuit is energized in response to a combination of the timer output and actuation of the start switch, energization of the start motor circuit being for the longer of the duration of the timer output and the start switch actuation.

3. The start motor control circuit of claim **2** in which the timer includes a monostable flip-flop actuated by said start switch and having an output with a duration independent of the time for which the start switch is actuated, the start motor circuit being energized by the output of the monostable flip-flop.

4. The start motor control circuit of claim **2** including a circuit providing time delay between the operator actuated start switch and the timer, to avoid false operation of the start motor circuit in the event of chatter of the start switch.

5. The start motor control circuit of claim 2 including a bistable flip-flop latch circuit having an input responsive to a combination of said timer output and actuation of the start switch, said bistable flip-flop having an output which effects energization of said start motor circuit.

6. The start motor control circuit of claim 5 in which said bistable flip-flop has a SET input, the control circuit including a circuit responsive to the occurrence at the same time of actuation of the start switch and an output from said timer to energize the start motor circuit.

7. The start motor control circuit of claim 6 in which said bistable flip-flop has a RESET input, the control circuit including a circuit responsive to the concurrent absence of actuation of the start switch and a timed output from aid timer, having an output connected with the RESET input of the bistable flip-flop to reset the flip-flop and terminate energization of the start motor circuit.

8. The start motor control circuit of claim 3 including a power source for the flip-flop, a vehicle disconnect switch in the circuit between the power source and the monostable flip-flop, closed by the operator to connect the power source with the circuit, said monostable flip-flop having a RESET input, and means operative on closure of the vehicle disconnect switch to generate a signal connected with the RESET input of the monostable flip-flop.

9. The start motor control circuit of claim 8 in which said last identified circuit is a two-input EX OR circuit having one input connected to the power source through the vehicle disconnect switch and with a time delay circuit connected between the power source and the other input, the output of said EX OR circuit being connected with the RESET input of the monostable flip-flop and occurring from closure of the vehicle disconnect switch until the end of the prior of the time delay circuit.

10. A fail safe control circuit for the start motor of a diesel engine, comprising: an operator actuated start switch; a start motor circuit; means responsive to actuation of said start switch by the operator to energize said start motor circuit; and a monitor circuit for comparing the condition of the start switch responsive means with the condition of the start motor circuit and for disabling the start motor circuit if they are not in the same condition.

11. The fail safe start motor control circuit of claim 10 including a time delay circuit between the monitor circuit and the means for disabling the control circuit if the start switch and control circuit conditions are not the same.

12. The fail safe start motor control circuit of claim 10 including a power source for the start motor circuit, a fuse in series with the power source and a high current load for said power source, said load being actuated in the event the start switch and control circuit are not in the same condition to blow the fuse and disable the start motor control circuit.

13. A fail safe control circuit for the start motor of a diesel engine, comprising: an operator actuated start switch; a start motor circuit; a monostable flip-flop timer actuated by said start switch and having an output with a duration independent of the time for which the start switch is actuated; means responsive to actuation of said start switch by the operator and to the timer output to energize said start motor circuit; and a monitor circuit for comparing the conditions of the start switch and the timer output with the condition of the start motor circuit and for disabling the start motor circuit if they are not in the same condition.

14. The fail safe start motor control circuit of claim 13 including a NOR circuit having inputs connected with the start switch and the timer output, said monitor circuit comparing the output of the NOR circuit with the condition of the start motor circuit.

15. A control circuit for the start motor of a diesel engine, comprising: an operator actuated start switch; a monostable flip-flop timer initiated by actuation of said start switch and having an output with a duration independent of the time for which the start switch is actuated; a bistable flip-flop latch circuit having an input responsive to a combination of said timer output and actuation of the start switch; and a start motor circuit energized by the output of said latch circuit.

16. The start motor control circuit of claim 15 in which said bistable flip-flop has a SET input, the control circuit including a circuit responsive to the occurrence at the same time of actuation of the start switch and an output from said timer, connected with said SET input.

17. The start motor control circuit of claim 15 including a monitor circuit for comparing the condition of the start switch with the condition of the start motor circuit and for disabling the start motor circuit if they are not in the same condition.

18. The start motor control circuit of claim 15 including a power source for the monostable flip-flop, a vehicle disconnect switch in the circuit between the power source and the monostable flip-flop, closed by the operator to connect the power source with the circuit, said monostable flip-flop having a RESET input, and means operative on closure of the vehicle disconnect switch to generate a signal connected with the RESET input of the monostable flip-flop.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,024,408

DATED : May 17, 1977

INVENTOR(S) : Donald F. Coleman and Richard H. Hoerr

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 34, change "Q" (second occurrence) to -- $\overline{Q}$ --;

Column 2, line 40, change "Q" to -- $\overline{Q}$ --;

Column 3, line 10, change "Q" (first occurrence) to -- $\overline{Q}$ --.

Column 5, line 39, change "prior" to -- period --.

Signed and Sealed this

Fifteenth Day of *November 1977*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

LUTRELLE F. PARKER
Acting Commissioner of Patents and Trademarks